The Properties of Convective Clouds Over the Western Pacific and Their Relationship to the Environment of Tropical Cyclones

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LONG-TERM GOALS

The long-term goal of the proposed work is to advance our understanding of the relationship between large-scale and mesoscale environmental conditions and small but powerful convective events during tropical cyclone (TC) development and intensity changes. Our ultimate goal is to identify the necessary conditions that determine the formation and evolution of a TC.

OBJECTIVES

With the data obtained during ONR's field program of " Tropical Cyclone Structure 2008 (TCS-08)" over the western Pacific region, the objective of this proposed study is to investigate large-scale environmental conditions, mesoscale phenomena and small scale convective bursts as well as their interactions that are responsible for TC formation and intensity changes. Specific areas include 1) Characterize the intensity of convection over the western Pacific oceans from radar, aircraft and satellite data; 2) Derive an accurate mesoscale environment of convective systems through the assimilation of satellite, radar, lidar and in-situ data; 3) Evaluate the quality of the global forecast system (e.g., Navy Operational Global Atmospheric Prediction System or NOGAPS) for accurate TC analyses and forecasts; 4) Understand the environmental factors that determine tropical cyclone formation and rapid intensification.

APPROACH

In order to achieve the research objectives of this proposal, our approach integrates observational data analysis, mesoscale data assimilation and forecast evaluations. This includes 1) analyzing TCS-08 field data in conjunction with the available satellite data products from Aqua and NASA Tropical Rainfall Measuring Mission (TRMM), 2) developing mesoscale data assimilation techniques to assimilate

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14. ABSTRACT
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satellite, radar, lidar and in-situ data into the Weather Research and Forecasting (WRF) and the Coupled Ocean/Atmospheric Mesoscale Prediction System (COAMPS®) mesoscale model(s), and 3) evaluating the performance of global ensemble forecasting to understand the quality of global forecasts and also study the predictability of TC formation and evolution. People involved in this project include PI (Dr. Zhaoxia Pu), her students (Andrew Snyder, Martin Schroeder) and a postdoctoral researcher (Dr. Lei Zhang), and NRL collaborators (Drs. Carolyn Reynolds and Allen Zhao).

WORK COMPLETED

Works completed in FY09 include:

(1) Mesoscale numerical simulations of TCS-08 typhoons with assimilation of satellite derived atmospheric profiles and airborne Doppler lidar wind observations

Research activities have been conducted to assimilate aircraft dropsondes and airborne Doppler wind lidar (DWL, aboard the NRL P-3) observations, collected during the T-PARC/TCS-08 field experiment and the Atmospheric Infrared Sounder (AIRS, aboard the NASA EOS Aqua satellite) derived temperature and moisture profiles into the WRF model to examine the impact of these data on the numerical simulation of typhoon formation and intensification, and concurrently, understand the dynamic and physical processes that control the formation and intensification of Western Pacific tropic cyclones. Four major typhoons (Jiangmi, Sinlaku, Nuri and Hagupit) have been studied. Transiting the data assimilation work to the COAMPS analysis system is also in progress.

(2) Tracking and verification of TC development in NOGAPS global ensemble forecasts

Using the software and methodologies developed in FY 08 with the NCEP global ensemble system, the NOGAPS ensemble system is evaluated in its performance of predicting TC genesis and evolution. Five cases of named TCs during the T-PARC/TCS-08 field program have been examined in detail to demonstrate the predictability of TC genesis and evolution in the NOGAPS ensemble products. The overall skill of ensemble forecasts, ensemble means and spreads, and probabilities in both pre-genesis and post-genesis stages are compared and evaluated. Two non-developing cases are also examined. Two different ensemble schemes, with and without stochastic convection, are compared based on their ability to produce accurate forecasts of TC genesis and evolution.

(3) Examining the relationship between precipitation characteristics and TC intensity changes

The evolution and structural changes of precipitation associated with TC genesis and intensification during TPARC/TCS08 field experiment are characterized. Possible relationships between the precipitation evolutions and TC intensity changes are examined. The 3-hourly, real-time merged multi-satellite precipitation products from TRMM and TC best track data from the Joint Typhoon Warning Center (JTWC) are used in this investigation.

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RESULTS

(1) *Impact of airborne Doppler wind lidar (DWL) profiles on numerical simulation of Typhoon Nuri's early rapid intensification*

During the TPARC/TCS08 field experiment in 2008, an airborne DWL was onboard the NRL's P-3 research flight. It was the first time the airborne DWL was used for tropical cyclone mission. Figure 1 shows the first results to demonstrate the impact of airborne Doppler Lidar wind measurements on numerical simulation of Typhoon Nuri (2008) in its formation phase. With the WRF model and its three dimensional data assimilation system, numerical results show a positive impact of the Airborne Doppler Lidar data on numerical simulation of Typhoon Nuri in terms of the storm track and intensity. For this particular case, assimilation of DWL profiles eliminated the northern bias of the simulated storm track. It also resulted in a stronger storm that is closer to the observed intensity of the storm.

The DWL wind profiles were compared with dropsondes released in the same area. Results show good agreement for measured winds. Different methods to assimilate the airborne DWL data were also compared. A four-dimensional data assimilation method is deemed to be more promising.

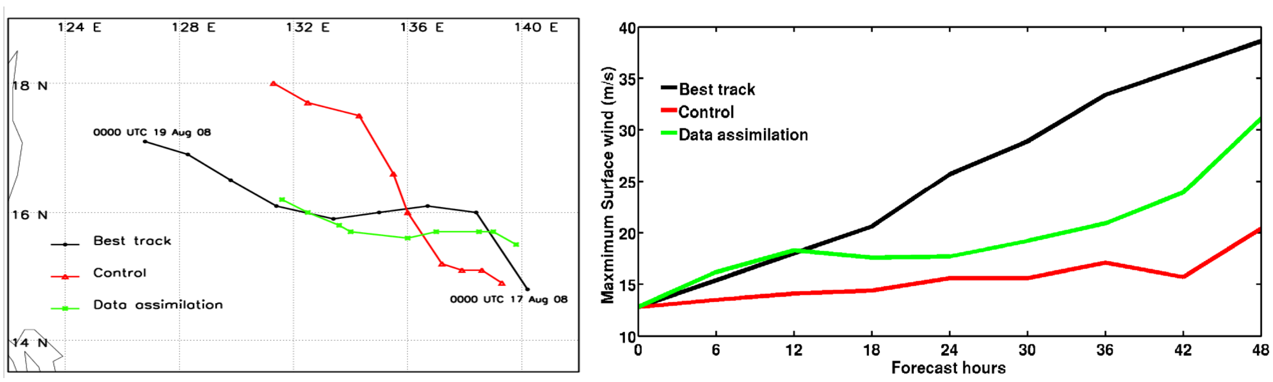

Figure 1: Impact of the airborne Doppler wind lidar (DWL) observations on the numerical simulation of Nuri's early rapid intensification. The figures show the track (left panel) and maximum surface wind (right panel) from 0000UTC 17 August 2008 to 0000UTC 19 August 2008. The forecasts with (green curves) and without (red curves) assimilation of DWL wind are compared with the JTWC best track data (black curves). DWL data are available and assimilated for the period of 0000 UTC – 0200 UTC 17 August 2008.

(2) *Impact of AIRS data on the numerical simulation of Typhoons Jangmi and Sinlaku*

The Atmospheric Infrared Sounder (AIRS) is aboard the NASA EOS Aqua satellite. It provides atmosphere temperature and moisture profiling information to support weather forecasting and climate research. The AIRS data is available at 45 km horizontal resolution and 28 pressure levels (1000mb -- .02mb). We have conducted two sets of numerical experiments with two typhoon cases during T-PARC/TCS08 to examine the impact of AIRS retrieved (Level 2) temperature and moisture profiles on numerical simulations of these typhoons. For both Typhoons Jangmi and Sinlaku, the assimilation of AIRS data resulted in significant improvement in track forecasts, although their impact on the storm intensity forecasts is marginal. Compared with the moisture profiles, temperature profiles have a larger impact on typhoon track forecasting.

Other studies were conducted to compare the AIRS retrieved temperature and moisture profiles with dropsonding data obtained from the TPARC/TCS08 field experiment. It is found that there is a cold (dry) bias for AIRS retrieved temperature (moisture) profiles. Bias corrections are helpful for improving data assimilation results. Without bias correction, the dry biases from moisture field could result in a decay of the storm.

(3) Comparison of two configurations of NOGAPS ensembles in TC forecasts

Two versions of the NOGAPS ensemble (with and without the addition of stochastic convection) were compared for their abilities in predicting formation, track and development of four typhoons (Nuri, Sinlaku, Hagupit and Jangmi), one tropical storm (Higos) and two non-developing systems (Waves TCS017 and TCS030). It is found that the overall forecast skill from the NOGAPS control ensemble (without stochastic convection) is relatively low, although it provides some additional information over the deterministic control in the tropics. The ensemble spreads are small and ensemble mean is similar to the deterministic control forecast. Including the stochastic convection improved ensemble forecasts as the ensemble spreads become larger and overall forecast accuracy for TC formation and track is enhanced. The ensemble spread also shows a better correlation to forecast track errors, especially in the post-genesis phase of TCs. However, it is also found that the weaker tropical systems could be over-intensified in the ensemble with stochastic convection.

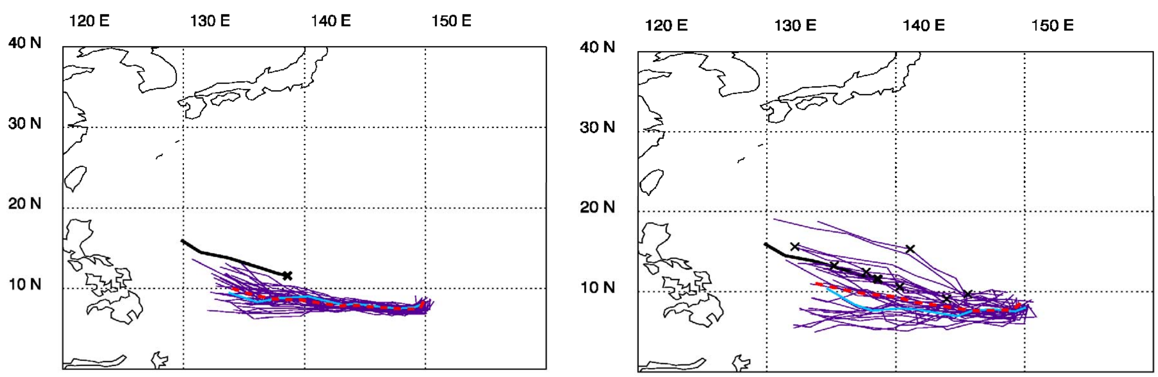

Figure 2: Tracking and verification of TC development in NOGAPS ensemble forecasts–a sample result. The left panel shows the tracks of 5-day control ensemble forecasts (without stochastic convection) from 00UTC 21 2008, 72 hours before Jangmi become a named tropical depression. The right panel shows the corresponding track forecasts from ensembles with stochastic convection. (Purple: forecasted tracks from 32 ensemble members. Red: ensemble mean track; Black: Actual track; An "X" indicates the forecasted TC genesis)

(4) Possible relationships between evolutions of precipitation and TC intensity changes

The 3-hourly, real-time merged multi-satellite precipitation products from TRMM and TC best track data from the JTWC are used to characterize the evolution of the precipitation features (e.g., the precipitation intensity, distribution and shapes of rainbands) around the core areas of those TPARC/TCS08 TCs during their life cycle (including formation, intensification and dissipating phases). It is found that the rainfall is generally intense during the tropical cyclone formation and

intensification but relatively weaker around the TCs' peak intensity. The rainfall structure tends to be more spiral shaped during the TC formation and weakening but becomes more organized during both the TC intensification and mature phases.

(5) Field data quality control

In collaboration with Dr. W.-C. Lee at NCAR, quality controls of EDORA radar data for data assimilation experiments are in process.

IMPACT/APPLICATIONS

The development of satellite and Doppler wind lidar data assimilation provides significant opportunities to study the environmental conditions of TC genesis, evolution and intensification. The evaluation of the performance of NOGAPS ensemble forecasts of TCs will also be helpful for the future development and improvement of ensemble forecast systems.

PUBLICATIONS

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